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Research Article

Determination of The Effect of Different Plant Densities and Nitrogen Doses on Agronomical Traits of Sweet Corn (*Zea mays* saccharata Sturt.) In Conditions of The Northern-East Transitional Region Conditions of Turkey

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Abstract

This study was carried out to determine the differences in yield and quality characteristics of different plant density and nitrogen doses in sweet corn (*Zea mays* L. *saccharata* Sturt) during 2017 and 2018 years. This research was conducted according to a split-plot design with three replications in the Bingol University Faculty of Agriculture Application and Research Farm. Vega sweet corn hybrid was measured with three intra-row spacing (15, 20, 25 cm) and five pure nitrogen doses (0, 80, 160, 240, 320 N kg ha^{-1}) were grown. In the study, the increasing nitrogen dose showed a significant rise in number of ears per plant , number of kernels per ear, relative chlorophyll content, water-soluble solids content, and fresh ear yield . It was determined that plant density positievly effected fresh ear yield; but the number of kernels per ear, the number of ears per plant, relative chlorophyll content were decreased. The highest fresh ear yield was determined D15 (13106 kg ha-1) in terms of plant density and N3 (15905 kg ha-1) in terms of nitrogen dose according to the combined experiment years analysis. Considering the average of years, 240 N kg ha^{-1} (N3) and approximately 100000 plants per hectare (S15) for optimum the fresh ear yield fertilizer application are recommended.

Keywords
Maize, yield, agromony, relative chlorophyll content, water-soluble solids content

INTRODUCTION

Maize (*Zea mays* L.) plant has highly differentiated features in terms of both botanical characters and beneficial characteristics. Sweet corn (*Zea mays* ssp. *saccharata*), one of maize subspecies known since the 18th century, has become more important. Sweet corn kernel has a high nutritional value which are proteins, vitamins, microelements, and sugars, and also a better taste. Sweet corn kernels are consumed both as fresh produce about 20% and in processed forms approximately 80% (Szymanek et al., 2006). Primary quality parameters in the products to be processed in the food industry are the kernel features such as the sugar content, the color, and yield (Öztürk et al., 2019).

Nitrogen is among the vital nutrients required by plants (especially N, P, K), which has a significant effect on the growth stages of maize (Casta et al., 2002). Specific nitrogen recommendations are essential for maximizing profits and productivity for sweet corn production. Stress factors, including nitrogen deficiency and competition between plants due to high plant density, reduce the ear size and the number of rows in the ear while also causing a decrease in yield (Khan et al., 2017).

In recent years agriculture production, plant density has a crucial role in increasing the yield (Sher et al., 2016). Also plant density is an important agricultural practice that causes changes in plant architecture, growth, and development patterns. It becomes limited by its carbon and nitrogen source, except for optimal plant density (Sangoi, 2001). Determining the optimum plant density to meet the increasing plant density and the corresponding increasing nutritional needs is an effective strategy (Gao et al., 2010; Sher et al., 2016). Also maize does not have a tillering ability, it cannot compensate for low plant density, resulting in a low final yield per unit area (Sangoi, 2001). Researches related to increasing the plant density in the unit area are an agricultural practice that is continuously and necessarily developed (Sher et al., 2016).

Sweet corn may be suitable for regions with a short vegetation period as Northern-East Transitional Region climate conditions due to a type of maize harvested during the milk setting period, such as sugar maize. Since the last frost date and the first frost date of a region are crucial factors that limit the planting time and thus sweet corn can be cultivated (Seydoşoğlu and Saruhan, 2017). In addition, it is of great importance to choose the most suitable maize hybrids for Northern-East Transitional Region climate conditions (Seydoşoğlu and Cengiz, 2020). Also, to our best knowledge there is no any study related to sweet corn in this spesific region. The objective of this study was to determine the effect of different plant densities and nitrogen doses on yield, yield-related, and quality traits in sweet corn under Northern-East Transitional Region climate conditions.

MATERIAL and METHODS

The sweet corn hybrid Vega was provided from MAY Agro Seed company. The hybrid is a super sweet corn hybrid, and matures between 76-80 days. We selected this hybrid for the study due to hybrid's huge sweet corn market share in Turkey.

A field trial was carried out at Bingol University Faculty of Agriculture Application and Research Farm, to know the performance of sweet corn under different plant densities and nitrogen doses in Bingol during 2017-2018 growing seasons. The area has a continental climate and climate conditions differ within the province depending on the variation in surface shapes (Avci et al., 2018).

Table 1. Mean temperature, total rainfall, and mean relative humidity properties of Bingol

	Years/Months	May	June	July	August	Mean	Total
Mean temperature (º C)	2017	16.3	22.2	28.0	27.6	23.25	-
	2018	16.4	22.6	27.1	27.4	23.38	-
	Long term (1970-2018)	17.4	21.3	25.0	24.6	22.08	-
Total rainfall (mm)	2017	74.8	21.2	7.3	4.3	-	107.6
	2018	163	33.3	4.6	-	-	200.9
	Long term (1970-2018)	77.1	21.0	8.4	5.1	-	111.6
Mean relative humidity (%)	2017	56.2	43.8	35.8	34.8	42.65	-
	2018	67.9	47.4	30.6	31.1	44.25	-
	Long term (1970-2018)	53.1	43.3	35.1	37.5	42.25	-

Source: Regional Directorate of Meteorology in Bingol

According to the climate data of Bingol (Table 1) for many years (1970-2018), the monthly mean temperature is 22.08 ºC and the monthly mean rainfall is 111.6 mm. The monthly mean temperature was 23.25 ºC in 2017 and 23.38 ºC in 2018. The monthly total rainfall (200.9 mm) of the research in 2018 is higher than the monthly total rainfall in 2017 (107.6 mm). The soil properties of the experimental area (0 -30 cm) are given in the Table 2. Soil pH was determined as slightly acidic and salt-free. The organic matter is low and insufficient as phosphorus and potassium content (Ülgen and Yurtsever, 1995).

Table 2. Soil properties of experimental location of Bingol

Year	Soil texture	Saturation (%)	EC (%)	pH	CaCO3 %	Organic Matter (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
2017	Loamy	45.6	0.022	6.57	0.6	1.76	37	214
2018	Clay-loam	52.9	0.023	6.5	1.3	1.91	46	232

Nitrogen fertilizer in the form of urea (46% N), and phosphorous and potassium fertilizer as compound fertilizer in consist of monoammonium phosphate (52% P_2O_5) and potassium oxide (34% K_2O) were used for the experiment. The treatments consisted of five rates of nitrogen 0 N kg ha^{-1} (N_0) , 80 N kg ha^{-1} (N_1), 120 N kg ha^{-1} (N_2), 160 N kg ha^{-1} (N_3), 240 N kg ha^{-1} (N_4), and 320 N kg ha^{-1} (N_5), fixed inter-row spacing of 70 cm, and three intra-row spacing of 15 cm (D_{15}), 20 cm (D_{20}), and 25 cm (D_{25}) with corresponding corn population of approximately 100000, 70000, and 60000 plants per hectare, respectively. A split-plot experimental design with three replications was used to comparison of these factors. The nitrogen dose were randomized in the main plot,and plant density were seperated in the sub-plots. The size of each subplot was 5 m × 2.8 m = 14 m^2. Certain methods were used for the properties examined in the research. The number of ears per plant was calculated by dividing the total number of ears harvested in the parcel by the number of plants for all the ears. The number of kernels per ear is found by counting the available kernels on ears taken randomly from each plot. The relative chlorophyll content of randomly selected plants from each plot was determined using the SPAD meter chlorophyll measuring device (SPAD 502 plus, Minolta, Japan). The water-soluble solids content was observed by this methodology, which is, the kernels which were squeezed and the milky endosperm fluid was left in the refractometer and determined in °Brix, which is an indirect expression of total sugar. Fresh ear yield was found, which is in all of the plants in the middle two rows of the plots, the fresh ears harvested from each plot were separated and weighed and the values obtained were converted to decares (Kırtok, 1998). Analysis of variance was performed according to the results obtained in the study according to a split-plot experimental design; Tukey test was used to compare the means of significant features. JMP 5.0.1 statistical package program was used to evaluate the research results (Anonim, 2002).

RESULTS and DISCUSSION

Water-soluble solids content

As stated in the Table 3, the effect of the interaction of nitrogen doses and density on the water-soluble was detected not significant. It was detected that a statistically significant difference between plant density and nitrogen dose in 2017, and only nitrogen dose in 2018. Evaluation of both years, due to the effect of nitrogen doses on the water-soluble solids changed between 13.13 °Brix (N_0) and 15.66 °Brix (N_4). Considering the plant densities, the highest amount of water-soluble solids was obtained 14.93 °Brix (D_{25}), but the lowest value was obtained 14.34 °Brix (D_{15}). Mean results both trial years of this characteristic evaluated, increasing nitrogen applications positively was affected. Increasing plant density changed positively in the content of water-soluble solids (Table 4). In the research conducted by Sakin and Sayaslan (2019) to determine certain quality characteristics of sweet corn hybrids, the ratio of water-soluble solids was found in the range of 10.7 to 21.2 °Brix. In the study examining the effects of different nitrogen doses on sweet corn, increasing nitrogen dose was found that the sucrose content increased (Bhatt, 2012).

Relative chlorophyll content

The effects of different nitrogen doses and plant densities on the relative chlorophyll content of the sweet corn were examined in the Table 3. Whereas the differences between plant density and nitrogen dose for the relative chlorophyll content in the trial years were statistically significant at the 1% probability level, no statistical significance was found between the interaction of these applications. The means of the years were examined, nitrogen applications for relative chlorophyll content were observed that the highest value was obtained in the N_4 (53.75 SPAD), while the lowest value was obtained N_0 (31.84 SPAD). The mean both years of values for plant densities, the highest relative chlorophyll content was obtained 45.53 SPAD (D_{25}), and the lowest value was obtained 41.47 SPAD (D_{15}). Significant increases in relative chlorophyll content were detected in the experiment due to increasing nitrogen doses. Relative chlorophyll content decreased with increasing plant density and these differences were found to be statistically significant (Table 4). Rostami (2008) and Tunalı et al. (2012) indicated that the increase in nitrogen doses causes significant increases in the chlorophyll content of plants. Ghimire et al. (2015) and Ya-wei et al. (2019) specified that significantly positive effect of relative chlorophyll content in yield. Similar results were observed by Tunalı et al. (2012) found the relative chlorophyll content in the range of 30.7-49.1 SPAD in their study conducted in Bursa, and by Taş and Öktem found the relative chlorophyll content in the range of 29.53 - 56.11 SPAD. Argenta et al. (2004) found relative chlorophyll content in the range of 45.4- 58.0 SPAD and this difference can depend are due to the differences in ecological conditions, hybrids, and agronomic processes.

Table 3. Variance analysis results of agronomic characteristics

	Variation Sources	Number of Ears Per Plant	Number of Kernels Per Ear	Relative Chlorophyll Content	Water-Soluble Solids Content	Fresh Ear Yield
2017	Nitrogen	**	**	**	**	**
	Density	**	**	**	**	**
	Nitrogen x Density	NS	NS	NS	NS	NS
	Coefficient of Variation (CV)	6.23 %	5.42 %	4.98 %	2.61 %	11.58 %
2018	Nitrogen	**	**	**	**	**
	Density	**	**	**	NS	**
	Nitrogen x Density	NS	NS	NS	NS	NS
	Coefficient of Variation (CV)	5.82 %	5.15 %	3.97 %	3.49 %	7.58 %
2017 - 2018	Years	NS	**	NS	NS	NS
	Nitrogen	**	**	**	**	**
	Density	**	**	NS	**	**
	Nitrogen x Density	NS	NS	**	NS	NS
	Coefficient of Variation (CV)	5.6 %	5.06 %	4.47 %	2.95 %	9.91 %

**P<0.01: Statistically highly significant; NS: Not significant

Number of Ears per Plant

According to the results, the effect of plant density and nitrogen fertilizer applications on number of ears per plant is given in Table 3. There was found that plant density and nitrogen dose applications were statistically significant during 2017-2018. No statistically significant differences were observed between the interaction of applications during trial years. The effect of years was found to be insignificant according to the combined variance analysis. According to the results of combined analysis, the number of ears per plant was ranged between 0.80 (N_0) and 1.03 (N_3). According to different plant densities, the highest number of ears was detected 0.97 from D_{25}, and the lowest value was found 0.84 from D_{15}. Similar observations for the number of ears was detected between years. Nitrogen doses increased noticeable changes on the number of ears. However, plant density negatively affected number of ears per plant and decreased the ear number in the plots (Table 4). The produce of ears can be depend plant densities due to competition (Rahmani et al., 2016). It is crucial for optimum yield that the number of ears per plant is 1-2 and productive ear per plant (Sönmez et al., 2013). In studies carried out in different ecologies, the number of ears per plant was found by Özkan (2007) and Turgut (2000) (0.885 to 0.975 and 0.6 to 1.1, respectively) and, these findings are similar to the values obtained in our research. The above studies showed that plant density decreased number of ear per plant. Similiarly, our results are similar to above mentined studies. However, the different range of this agronomic characteristic was stated by Rahmani et al. (2016) and Sönmez et al. (2013) (1.89-2.41 and 1.60-1.96, respectively). It is assumed that the difference from our study is due to the differences in ecological conditions, , and agronomic processes.

Table 4. Mean values of number of ears per plant, water-soluble solids content, and relative chlorophyll content

		Number of Ears Per Plant			Water-Soluble Solids Content (ºBrix)			Relative Chlorophyll Content (SPAD)		
		2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Nitrogen	N_0	0.79 d	0.79 c	0.80 d	12.90 d	13.35 c	13.13 d	31.20 d	32.48 d	31.84 e
	N_1	0.85 cd	0.83 c	0.84 d	13.82 c	13.94 c	13.88 c	36.03 c	37.19 c	36.61 d
	N_2	0.90 bc	0.92 b	0.92 c	14.73 b	14.63 b	14.68 b	47.66 b	44.28 b	45.97 c
	N_3	1.03 a	1.01 a	1.03 a	15.70 a	15.32 a	15.51 a	49.44 b	52.18 a	50.81 b
	N_4	0.95 b	0.98 ab	0.97 b	15.98 a	15.33 a	15.66 a	53.70 a	53.80 d	53.75 a
Density	D_{15}	0.90 b	0.83 c	0.84 c	14.36 b	14.32	14.34 b	40.92 b	42.02 c	41.47 b
	D_{20}	0.97 a	0.92 b	0.92 b	14.41 b	14.49	14.45 b	44.82 a	43.96 b	44.39 a
	D_{25}	1.01 a	0.97 a	0.97 a	15.11 a	14.74	14.93 a	45.08 a	45.97 a	45.53 a

Table 5. Mean values of number of kernels per ear and fresh ear yield

		Number of Kernels per Ear			Fresh Ear Yield (kg ha^{-1})		
		2017	2018	Mean	2017	2018	Mean
Nitrogen	N0	387.49 d	397.44 d	392.47 d	6500 d	7503 e	7001 d
	N1	488.03 c	422.22 d	455.13 c	9074 c	9045 d	9060 c
	N2	538.52 b	465.33 c	501.93 b	12566 b	11331 c	11948 b
	N3	593.66 a	574.22 a	583.94 a	15900 a	15911 a	15905 a
	N4	608.40 a	540.89 b	574.64 a	15395 a	14540 b	14968 a
Density	S15	498.91 b	465.87 b	482.39 c	13079 a	13133 a	13106 a
	S20	524.33 ab	474.53 b	499.43 b	12095 a	11523 b	11809 b
	S25	546.43 a	499.67 a	523.05 a	10486 b	10342 c	10414 c

Number of Kernel per Ear

Differences in plant density and nitrogen fertilizer applications in the number of kernels per ear were examined, and it was detected that the ranges in plant densities and nitrogen doses were statistically noticeable in trial years. The interaction of plant density and nitrogen dose was found to have a not significant effect on the number of kernels on the ear (Table 3). The number of kernels on the ear ranged from 387.49 to 608.40 in 2017, and from 397.44 and 574.22 in 2018 in the research. In terms of nitrogen applications of the combined years, the highest value for the number of kernels per ear was found 583.94 (N_3), and the lowest value was found 392.47 (N_0). Data on the number of kernels per ear was determined particularly N_3 to be highest and N_0 to be lowest in both years. Results for plant densities in both combined years were analyzed that was indicated the highest number of kernels per ear was obtained 523.05 from S25, and the lowest was obtained 482.39 from S15 (Table 5). As a result, it was determined that increasing nitrogen dose affected a positive change in the number of kernels per ear. But increasing plant density provided a noticeable significant decrease in the number of kernels per ear. High plant populations can cause sterility since stimulating apical dominance in the plant. It may cause a decrease substantially in yield because it reduces the number of seeds in the affecting ear produced per plant (Sangoi, 2001). The negative effect of increasing density has been emphasized by some researchers (Dhaliwal and Williams, 2019; Raja, 2001). The effect of the number of kernels per ear can change the ear yield over 90 percent (Khazaei et al., 2010). Optimum nitrogen dose varies according to environmental conditions, the characteristics of the hybrid used, and different applications. Nitrogen fertilization in sweet corn increased the number of kernels per ear was reported by Bhatt (2012) and Raja (2001).

Fresh ear yield

According to the results of fresh ear yield; the differences in plant density and nitrogen dose were significant, but the interaction of these applications was not observed during the trial years (Table 3). In terms of nitrogen applications of the combined years in the experiment, N_3 application gave the highest value with 15905 kg ha^{-1}, and the lowest value was obtained at 7001 kg ha^{-1} in N_0 application. For comparisons between nitrogen applications of the combined years in the study, the fresh ear yield was recorded the highest value for N_3 and the lowest for N_0. For combined experiment years, The fresh ear yield was obtained the highest from D_{15} and the lowest in D_{25}, while plant densities were compared (Table 5). As an outcome, increasing nitrogen doses provided a partial increase in the results of the fresh ear yield and these differences had statistical significance. Increasing plant density, there were positive changes in the mean results of the fresh ear yield . The fresh ear yield was reported by Öktem and Öktem (2006) 8385 to 16370 kg ha^{-1}, Erdal et al. (2011) 7700 to 12000 kg ha^{-1}, Sönmez et al. (2013) 19340 to 23250 kg ha^{-1} and Rahmani et al. (2016) between 12790 and 23690 kg ha^{-1}. Bozkurt and Karadoğan (2017) observed that increasing plant density has reduced yield. Positive effects of nitrogen doses on yield were reported by Stone et al. (1998), Akbar et al. (2002), Özkan (2007), and Khan et al. (2017).

CONCLUSION

Sweet corn is noteworthy for short vegetation period regions due to high kernel moisture problem at harvest, according to the two-year data, while the increase in nitrogen content has a positive effect on the examined properties, no difference was found between N_3 (240 N kg ha^{-1}) and N_4 (320 N kg ha^{-1}) on water-soluble solids, number of kernels per ear and the fresh ear yield . Increasing plant density had negative effects on the number of ears per plant, water-soluble solids, relative chlorophyll content and the number of kernels per ear. As a results of combined years , 240 N kg ha^{-1} (N3) and approximately 100000 plants per hectare (S15) for optimum the fresh ear yield fertilizer application are suggested for Vega hybrid in Bingol.

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